

# BASIC PRINCIPLES OF MRI SAFETY

John C. Posh, RT(R)(MR)

## INTRODUCTION

A working knowledge of safety issues related to technologists using magnetic resonance imaging (MRI) is presented here. The interested reader will become familiar with the three types of magnetic fields used in MRI. The reader will also gain a general understanding of the bio-effects of these magnetic fields as well as the effects they can have on biomedical implants, foreign bodies, and support equipment. Proper preparation and screening procedures for patients will also be discussed here.

The field of MRI safety can be separated into two general categories. The first category covers the bio-effects of exposure to the three types of magnetic fields used. The second category deals with the effects those fields can have on implants, foreign bodies, and support equipment. This article is not intended to be a definitive work but rather a general overview of the issues related to MRI safety.

## MRI MAGNETIC FIELDS

The following three magnetic field types are used in MRI:

1. Static magnetic field created by the main magnet assembly
2. Time-varying or gradient magnetic fields created by the gradient coils
3. Radiofrequency (Rf) magnetic fields created by the Rf transmitters

## STATIC MAGNETIC FIELD

The *static magnetic field* is the main magnetic field in MRI that is used to align the patient's protons in an organized and predictable fashion. It is represented by the symbol  $B_0$ . The static magnetic field is measured in

the exact center of the magnet at the intersection of the three orthogonal planes (X, Y, Z). This central point is called the isocenter.  $B_0$  is measured at the isocenter because that is where the imaging process occurs; therefore, this is the point at which the static field must be precise. The strength of the static field ( $B_0$ ) is measured in tesla (T), with one tesla equal to 10,000 gauss (G). The portion of the static field that extends outside the bore of the magnet is called the *fringe field*; this field is measured in gauss units. The fringe field should be less than or equal to 5 G at the outside perimeter of the room. High-field superconducting MR imagers that are used for clinical scanning typically operate at 1.5 T (or 15,000 G). However, there are special-purpose magnets in use at several universities and research facilities with fields as strong as 4.0 to 5.0 T. The U.S. Food and Drug Administration (FDA) currently limits clinical-strength magnets to below 4.0 T.

Exposure to static magnetic fields has not been found harmful to patients undergoing MRI examinations at clinical strength. Although MRI has been found safe at commonly encountered clinical strength, there are some bio-effects that may be observed. The severity of these effects is generally related to the strength of the field and the overall health of the patient.

One phenomenon that has been observed at 1.5 T and as low as 0.1 T is a *magneto-hydrodynamic effect*.<sup>1</sup> When a conductor moves through a magnetic field (or a stationary conductor is exposed to a moving or gradient magnetic field), a current is induced in the conductor. The blood flowing through the heart creates this effect. The current induced in the blood can be seen as an elevation of the S-T segment on the patient's electrocardiogram. The degree of change is directly related to the strength of the magnetic field. At higher field strengths, this elevation is so pronounced that it can trigger the acquisition process in a cardiac gated study.<sup>2</sup> This change is present only when the patient is in the bore of the magnet, and it is not associated with any serious bio-effects. However, because an elevated S-T segment can be indicative of myocardial infarction, ischemia, or an electrolyte imbalance, it is imperative that any patient with compromised cardiovascular function be closely monitored with an MRI-compatible pulse oximeter and/or blood pressure monitor.

## CRYOGENS

*Cryogenic liquids* are used to maintain the superconductivity of the main magnet in MRI scanners. The cryogens used are either liquid helium and/or nitrogen, depending on the age of the scanner. The newer scanners use only liquid helium. The cryogens are held in a highly insulated vacuum chamber called the *cryostat*. The risks associated with cryogenic liquids are related to their extremely low temperatures. Liquid helium cannot exist above approximately 4° K, and liquid nitrogen must be kept below approximately 77° K. An increase in the temperature of the cryogens can cause them to revert to their gaseous form. When they start to boil off, they increase the temperature of the magnetic windings that in turn increases the resistance. The resistance allows some of the circulating electricity to be lost as heat, which increases the temperature of the cryogens even more. The rising temperature of the cryogens allows them to revert to their gaseous form, expanding up to 760 to 1 (ie, 1 liquid liter of Helium evaporates into 760 cubic liters of gas). This phenomenon escalates until the pressure in the cryostat increases to such a high level that the safety valve (also called a *burst disk*) explodes. Without the burst disk, the cryogenic gasses are rapidly vented from the cryostat. This is called a *quench*. The venting system should carry the gasses outside the MRI facility where they can be safely released into the air. Should the venting system fail, the cryogens could enter the scan room and place the patient at significant risk. A quench can place the patient at risk for hypothermia and/or burns due to the extremely low temperature of the cryogens. A quench can also create a suffocation hazard for the patient by displacing all of the oxygen in the room. Remember, helium expands from 1 L of liquid to 760 L of gas. Some magnets can hold 800 L of liquid helium.

### EQUATION 1

$$800 \text{ (L liquid He)} \times 76 \text{ (expansion per liter)} = 608,000 \text{ L}^3 \text{ of gas}$$

An average-sized scan room normally holds approximately 9600 L<sup>3</sup> of air.

### EQUATION 2

$$608,000 \div 9600 = 63.30 \times \text{normal volume of room air}$$

In the event of a quench, all patients and staff should immediately be evacuated from the scanner area. To date, there are no reports of a patient or healthcare worker getting injured as a result of a quench.<sup>2</sup>

## GRADIENT MAGNETIC FIELD

The second type of magnetic field used in MRI is the *time-varying* or *gradient magnetic field*. Gradient magnetic fields are created by the cycling of power through the gradient coils, hence the name gradient magnetic fields. The gradient magnetic fields are used to control the selective excitation of the patient's protons. The strength of gradient fields is measured in G/cm. Routine scanners use gradients that operate at 5 to 10 G/cm. The newest echo-planar systems operate with gradients of 25 G/cm and above. Additionally, the speed of the gradients is also important. A strong gradient that rises from baseline to maximum power in 600 μ sec is less likely to induce a current than a gradient that rises to baseline in less than 200 μ sec.

Gradient fields can induce a current in any conductor. The magnitude of an induced current depends on the strength and speed of the gradient fields and the resistance of the conductor. The human body has several excellent conductors: nerves, muscles, and blood. If a current were induced, the type of clinical manifestation experienced by the patient would depend on the type of tissue in which the current was induced. Direct stimulation of peripheral nerves could cause muscle contractions or sensations of tingling and itching, depending on whether the stimulated nerve is a sensory or motor nerve. Direct stimulation of the retina and/or optic nerve can be experienced by the patient as flashes of light. This phenomenon is known as *magnetophosphenes*. Direct stimulation of muscles can cause the stimulated muscle to contract. If the stimulation is in cardiac muscle, it could theoretically disrupt the normal cardiac cycle and lead to an arrhythmia.<sup>1</sup> It should be noted that the density of current required to elicit this response in healthy skeletal muscle is between 5 and 20 times higher than the current densities produced by routine clinical scanners.<sup>1</sup> However, ultrafast [echo-planar] systems are now available and quite capable of direct peripheral nerve stimulation.<sup>1</sup> This effect is not likely to occur with clinical-strength magnets, but it has been experienced in the presence of higher field-strength research magnets. The FDA has specified that the exposure to gradient magnetic fields be limited to those fields with strengths that are (1) significantly less than those required to produce peripheral nerve stimulation or (2) less than 6.0 T/sec.<sup>3</sup>

## RADIOFREQUENCY MAGNETIC FIELD

The third type of magnetic field used in MRI is the Rf magnetic field. Radio waves are used to excite the patient's protons within the stable magnetic field. The primary effect of Rf radiation (ie, energy) on biologic tissues is heating due to resistive losses. In effect, the same principles as those in a microwave oven are being used, only at a significantly lower power. The human body has a very efficient thermoregulatory system and can handle

reasonable changes in temperature. For example, think of the patient lying in the sun at the beach. Which is hotter after 90 minutes, the surface of the patient or the surface of the sand? The sand is obviously the hotter of the two. The patient's body can respond to the temperature increase. One way in which the body does this is by increasing capillary flow so the blood will pull the heat from the tissues. There are two areas, however, that cannot quickly dissipate the heat. These two areas—the eyes and testicles—have poor capillary networks that cannot dissipate the heat as fast; therefore, they are at a slightly increased risk of thermal injury. However, the risks are believed to be minimal. It is believed that patients with no predisposing conditions that would increase their sensitivity to thermal changes can safely undergo MRI examinations at current clinical strength.<sup>1</sup> The amount of energy deposited in tissues is expressed as the specific absorption rate (SAR). SAR is measured in watts per kilogram, and the current limit as set by the FDA is: (1) 0.4 W/kg for whole body exposure; (2) 8.0 W/kg peak in any 1 g of tissue; and (3) 3.2 W/kg average to the head. With this in mind, we can see that a 200-kg man can absorb higher levels of Rf for a longer period of time than a 22-kg child. A study measuring temperature changes in patients subjected to MRI at SAR levels up to 4.0 W/kg (10 times the current FDA limit) found no statistically significant increase in skin or body core temperature<sup>4</sup>; this indicates that MRI with currently approved SAR levels is probably without risk (for Rf injury) in an otherwise healthy individual.

## MRI EFFECTS

### PREGNANCY

There are two separate issues to be addressed when discussing MRI and pregnancy. The first deals with MRI and pregnant technologists or other healthcare workers. Because healthcare workers are not exposed to the gradient or Rf magnetic fields, it is commonly believed that they are not at risk for pregnancy complications attributable to MRI. A survey of female healthcare workers published in 1993 by Kanal and coworkers<sup>5</sup> surveyed 1,915 female healthcare workers regarding reproductive and menstrual history. Based on the results of those surveys, the authors concluded that there are no obvious risks. Even a technologist who stays in the room during the MRI examination is really only exposed to the static field, because the gradient and Rf fields are markedly weaker outside the bore of the scanner. It is generally good policy, however, to minimize a pregnant technologist's exposure to any magnetic fields during the first trimester.

The second issue of MRI and pregnancy involves pregnant patients. Because of the great diagnostic value of MRI, it may frequently be the test of choice even in

a pregnant patient. Little is known about the effects of magnetic fields on developing human embryos. The present belief is that MRI has not produced any negative effects in pregnant humans. Despite this belief, the patient should be informed that the FDA has not established that MRI during pregnancy is safe.<sup>1</sup> The referring physician must decide if the diagnostic benefits of the test outweigh any potential risks. Potential risks could include birth defects, developmental abnormalities, low birth weight, and spontaneous abortion. The decision of the referring physician also needs to be discussed with the patient's obstetrician. If both the referring physician and obstetrician feel that the test is indicated, then the patient should be scanned. In cases of serious illness or injury, the examination should be performed as soon as possible. If the illness or injury is not immediately life-threatening, the examination should be postponed until the end of the first trimester.

### ACOUSTIC NOISE

The now-famous noise associated with MR scanning is an area that needs to be addressed. The noise is created when the gradient coils vibrate on their mountings as a result of the rapidly cycled gradient magnetic fields. The noise levels generated by the gradient fields have been measured at levels ranging from 84 to 103 decibels.<sup>1</sup> The actual level of the noise depends on the slice thickness, field of view, and scan timing of the examination. Acquisitions with high resolution, thinner slices, and smaller fields of view are noisier due to the increased *slope* of the gradient. The slope refers to the degree of change in gradient strength over a given distance. It has been reported that 43% of patients who were scanned without hearing protection experienced temporary hearing loss.<sup>6</sup> The best way to protect patients from MRI-associated noise is with foam-rubber earplugs. The earplugs are available from the scanner manufacturer and several third party vendors. They are inexpensive, disposable, and effective. Commercially available earplugs can reduce the noise levels associated with MRI by as much as 20 decibels.<sup>1</sup> There are also commercially available noise cancellation systems or anti-noise systems that reportedly can lower the noise levels by up to 70%.<sup>1</sup>

### EFFECTS OF MAGNETIC FIELDS ON METALLIC MATERIALS

The magnetic fields used in MRI can have three different effects on metallic foreign bodies, implants, and patient care support equipment.

**Torque.** Metallic foreign materials will align with and be attracted to the main magnetic field if taken into the room. The greatest risk comes from ferromagnetic (iron-containing) materials. Ferromagnetic materials will become projectiles around clinical field strength magnets. A partial list of some of the materials that have been

attracted to, or found in, MRI scanners can be found in Table 1. Ferromagnetic implants and foreign bodies can also align with the magnetic field. The potential for an injury depends on the strength of the magnetic field, type and location of the implant, physical dimensions and orientation of the implant, and length of time the implant has been in place.

**TABLE 1. Items Found in MRI Scanners**

Bras	Lighters	Stethoscopes
Hairpins	Mops	Watches
IV poles	Oxygen cylinder	Tools
Clipboards	Paper clips	Spray cans
Floor buffers	Pens	Staples
Buckets	Sandbags	Wheelchairs
Coins	Spoons	Stretchers
Jewelry	Staplers	Tile cutters

The two greatest potential complications of implant-related torque are the eyes and brain. Small metal fragments in or around the eyes could migrate in the presence of a sufficiently strong magnetic field. In 1986, Kelly and coworkers<sup>7</sup> reported on a patient who was blinded in one eye due to the migration of a 2.0- x 3.5-mm metal fragment in the field of a 0.35-T MR scanner. All patients with a history of metal-related eye injury and/or sheet metal work or welding or without positive confirmation of the absence of intra-ocular metal should be screened with conventional x-rays before undergoing MRI. Research has indicated that metal fragments too small to be seen on conventional radiographs (ie, smaller than 0.1 x 0.1 x 0.1 mm) are too small to damage the ocular tissue.<sup>2</sup> Although computed tomography may offer better resolution, this procedure is probably unnecessary in the presence of a negative x-ray finding.<sup>1,2,4</sup> Also, because intracranial aneurysm clips can be ferromagnetic, implants in the brain should be approached with caution. There has been a report of a fatality in MRI due to the migration of an intracranial aneurysm clip in a 1.5-T MR scanner.<sup>2</sup> All patients with intracranial aneurysm clips should be excluded from MRI unless the clip was tested before implantation. If the clip demonstrates no attraction, it is probably MRI-compatible and the patient's operative notes should be annotated accordingly.

**Induced Current.** Faraday's law of induction states that a current can be induced in a conductor by a moving magnetic field. The gradient fields associated with routine clinical MRI procedures are unlikely to induce a current in healthy biologic tissues. However, metallic implants

and foreign bodies could increase the potential for current induction. The relatively greater conductivity of metallic implants, wires, and/or foreign bodies could allow sufficient current to be induced to elicit a response. Any current induced by MRI (in anything other than a coil) can be very dangerous. If this current were to be delivered directly to the cardiac muscle via a residual pacemaker wire or pacing catheter, it could be sufficient to cause an arrhythmia.<sup>1,2</sup>

**Heating.** Gradient magnetic fields and Rf magnetic fields can cause heating in metallic implants and foreign bodies. The changing magnetic fields induce a current in the implant (ie, foreign body). Without a pathway to exit the body, the current builds up, and the implant gets warm. The degree of warming depends on the strength and rate of change of the magnetic field and the conductivity of the implant. Military shrapnel, metal slivers, and wires are all susceptible to heating. If these items are located in or around the eyes, spine, heart, or brain, serious and irreversible damage can occur.

**Projectiles.** A ferromagnetic object can reach speeds of up to 45 miles per hour on its way into a 1.5-T magnet. The actual attractive force that a ferromagnetic object experiences will depend on the strength of the magnetic field, mass of the metal object, and the object's distance from the center of the bore. The strength of attraction is inversely proportional to the square of the distance, that is, the force doubles as the object's distance from the bore is halved. All equipment—no matter what its function—should be tested with a strong hand magnet of at least 3000 G before it is used in or around the MR scanner. If the equipment is found safe after testing, it should be labeled as MRI-safe and used only in the MRI suite. Any piece of equipment that exhibits even a slight attraction should be labeled as ferromagnetic and excluded from use around the scanner.

**Pacemakers.** There are approximately 80,000 pacemakers implanted into patients in the United States every year. When the surgeon implants the pacemaker, it is activated and remains on until either the battery runs out or the pacemaker is removed. The surgeon programs and tests the pacemaker with a hand-held magnet. The magnet opens a reed switch (a small switch opened by the application of an external magnetic field) and activates the pacemaker. If the patient is exposed to any additional magnetic fields such as those found in MRI, the pacemaker could be deactivated or malfunction. Also, the various magnetic fields used in MRI could induce a current in the pacing wires. If the current, however small, were delivered directly to the cardiac muscle, it could lead to cardiac fibrillation. There has been a report of a patient with a pacemaker who died of cardiac arrest that was presumably induced by MRI.<sup>1</sup> Internal pacemakers, external pacemakers, pacing catheters, and internal defibrillators are all possible contraindications to the use of MRI. Only the physician in charge of the patient's care and an experienced MR radiologist should decide if the benefits of performing the MRI outweigh the potential risks.

## WORKING WITH THE PATIENT UNDERGOING MRI

### PATIENT SCREENING

By far the best screening tool for MRI is a well-trained technologist. No device or gadget can replace proper training and experience when it comes to patient screening. Metal detectors are an expensive waste of time and may cause more harm than good by instilling a false sense of security. Metal slivers in the eye are much too small to set off the metal detector, but as previously described, they can be disastrous if taken into the magnetic field. The best way to screen a patient is to obtain a detailed history. The history should include a list of all previous surgeries and procedures. The patient's occupational history should also be obtained to decide if the patient is at risk for the presence of metallic foreign bodies in the eyes. Sheet metal workers, machinists, and welders are at high risk for having metallic foreign bodies.

### PATIENT PREPARATION

Patient preparation involves many steps. The patient should be instructed to wear loose, comfortable clothing without zippers, snaps, or buttons. Clothing decorated with decals and sequins should be avoided. For most examinations, patients can wear elastic-waist, cotton sweat pants and a plain T-shirt. Female patients should wear a sports bra without hooks or snaps; any other type of bra should be removed before the patient enters the room. All accessories should be removed. Accessories include rings, bracelets, watches, earrings, and body piercings. Face and eye make-up should also be removed. If the patient arrives wearing clothes with zippers or other metal, he/she should change into an appropriate gown. The gowns should have loose-fitting sleeves so that the technologist can check for watches and bracelets; loose sleeves are also an asset if the patient requires an injection of contrast agent. The patient gowns should not have pockets. It will be much more difficult for a patient to accidentally bring contraindicated materials into the room without pockets.

### PATIENT HISTORY

Radiologists don't always have the opportunity to speak with patients directly, so they rely on the technologists to provide them with the detailed history they need. This history should include previous examinations of the same body part, surgery or other procedures to the same body part, and any pathology associated with the body part. For many pathologic conditions, a detailed family history may be helpful, and space for this history should be included on the patient screening form (Attachment A). A medical history is extremely important if the patient is

to receive an intravenous (IV) contrast agent. No patient should be given IV contrast without first questioning him/her about medical history (specifically, diabetes, hypotension, anemia, asthma, renal disease, and sickle cell disease) as well as drug allergies. Intravenous MRI contrast is a drug. It should be given under the supervision of a physician and only when indicated (ie, lesions of the brain and spinal cord with abnormal vascularity or that disrupt the blood-brain barrier, lesions of the spine and associated tissues, and lesions of the body [excluding the heart]).<sup>8</sup> There are of course many additional indications for contrast that are currently accepted as the standard of clinical practice such as contrast enhanced MR angiography (CEMRA) as well as some off label uses such as MR arthrography. Whatever the reason for administration it is essential that the facility is prepared to treat any reaction should it occur.

### PATIENT ANXIETY

Patients arriving for an MRI examination usually fit into one of two categories: either they have no understanding of the procedure, or they have heard dozens of horror stories from friends and neighbors who have all undergone the test. The chances of a patient canceling the examination because of anxiety are greatly reduced if the procedure is properly explained to the patient. It is a good idea to explain the procedure before the patient enters the room. The anxiety level produced by the MR scanner can be decreased by allowing an appropriately screened family member to remain in the room with the patient during the examination. Providing a calm environment with subtle lighting can make the examination much less stressful. All patients should be offered music if available. Some patients will respond well to soft classical music, whereas others will do better with something louder but familiar to them.

### CONCLUSION

MRI is a fairly young imaging tool, and although much research has been done on the safety of MRI, there is still a lot to be learned. The scanners are becoming stronger and faster, so the potential for MRI-related injuries is becoming greater. New implants and devices are developed almost daily. This means that there are new safety concerns for MRI almost daily. The magnetic fields used in MRI cannot be felt, heard, or seen; however, these magnetic fields must be respected. A working knowledge of MRI safety is not a luxury; it is a fundamental and integral part of being an MRI technologist.


### REFERENCES

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APPENDIX 2. MR SCREENING FORM FOR PATIENTS, PAGE 2

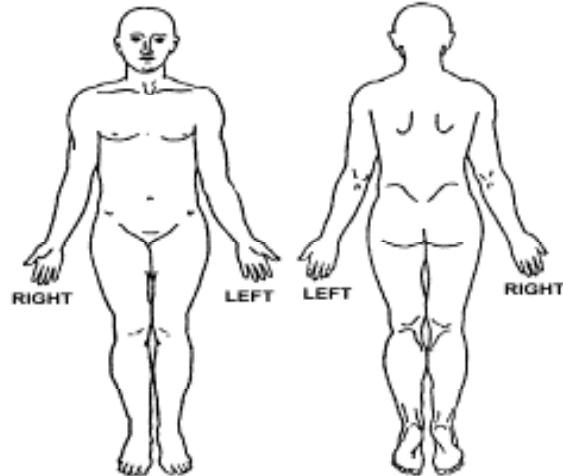


**WARNING:** Certain implants, devices, or objects may be hazardous to you and/or may interfere with the MR procedure (i.e., MRI, MR angiography, functional MRI, MR spectroscopy). **Do not enter** the MR system room or MR environment if you have any question or concern regarding an implant, device, or object. Consult the MRI Technologist or Radiologist **BEFORE** entering the MR system room. The MR system magnet is **ALWAYS** on.

Please indicate if you have any of the following:

- Yes  No Aneurysm clip(s)
- Yes  No Cardiac pacemaker
- Yes  No Implanted cardioverter defibrillator (ICD)
- Yes  No Electronic implant or device
- Yes  No Magnetically-activated implant or device
- Yes  No Neurostimulation system
- Yes  No Spinal cord stimulator
- Yes  No Internal electrodes or wires
- Yes  No Bone growth/trauma fixation stimulator
- Yes  No Cochlear, otologic, or other ear implant
- Yes  No Insulin or other infusion pump
- Yes  No Implanted drug infusion device
- Yes  No Any type of prosthesis (eye, penis, etc.)
- Yes  No Heart valve prosthesis
- Yes  No Eyelid spring or wire
- Yes  No Artificial or prosthetic limb
- Yes  No Metallic stent, filter, or coil
- Yes  No Shunt (spinal or intraventricular)
- Yes  No Vascular access port and/or catheter
- Yes  No Radiation seeds or implants
- Yes  No Swan-Ganz or thermalablation catheter
- Yes  No Medication patch (Nicotine, Nitroglycerine)
- Yes  No Any metallic fragment or foreign body
- Yes  No Wire mesh implant
- Yes  No Tissue expander (e.g., breast)
- Yes  No Surgical staples, clips, or metallic sutures
- Yes  No Joint replacement (hip, knee, etc.)
- Yes  No Bone/joint pin, screw, nail, wire, plate, etc.
- Yes  No IUD, diaphragm, or pessary
- Yes  No Dentures or partial plates
- Yes  No Tattoos or permanent makeup
- Yes  No Body piercing jewelry
- Yes  No Hearing aid  
(Remove before entering MR system room)
- Yes  No Other implant
- Yes  No Breathing problem or motion disorder
- Yes  No Claustrophobia

Please mark on the figure(s) below the location of any implant or metal inside of or on your body.





**IMPORTANT INSTRUCTIONS**

Before entering the MR environment or MR system room, you must remove all metallic objects including hearing aids, dentures, partial plates, keys, beeper, cell phone, eyeglasses, hair pins, barrettes, jewelry, body piercing jewelry, watch, safety pins, paperclips, money clip, credit cards, bank cards, magnetic strip cards, coins, pens, pocket knife, nail clipper, tools, clothing with metal fasteners, & clothing with metallic threads.

Please consult the MRI Technologist or Radiologist if you have any question or concern **BEFORE** you enter the MR system room.

**NOTE:** You may be advised or required to wear earplugs or other hearing protection during the MR procedure to prevent possible problems or hazards related to acoustic noise.

I attest that the above information is correct to the best of my knowledge. I read and understand the contents of this form and had the opportunity to ask questions regarding the information on this form and regarding the MR procedure that I am about to undergo.

Signature of Person Completing Form: \_\_\_\_\_ Date: \_\_\_\_/\_\_\_\_/\_\_\_\_  
Signature

Form Completed By:  Patient  Relative  Nurse \_\_\_\_\_  
Print name Relationship to patient

Form Information Reviewed By: \_\_\_\_\_  
Print name Signature

MRI Technologist  Nurse  Radiologist  Other \_\_\_\_\_



## BASIC PRINCIPLES OF MRI SAFETY POST TEST

Expires: July 15, 2011 Approved for 1 ARRT Category A Credit.

1. **What is the function of the static magnetic field?**
  - a. Augmentation of the gradient field(s)
  - b. Alignment of protons
  - c. Excitation of protons
  - d. Storage of raw data
2. **What does the symbol  $B_0$  represent?**
  - a. Gradient magnetic field
  - b. Static magnetic field
  - c. Available memory
  - d. Number of protons imaged
3. **The place where the three orthogonal planes (X, Y, Z) meet is called the**
  - a. hypercenter.
  - b. isocenter.
  - c. hypocenter.
  - d. logical center.
4. **The static magnetic field is commonly measured in**
  - a. ohms.
  - b. gauss.
  - c. tesla.
  - d. W/kg.
5. **One tesla is equal to**
  - a. 1000 G.
  - b. 10,000 G.
  - c. 16 kHz.
  - d. 1 unit of force times the resistance in an electro-magnet at absolute zero.
6. **What is the current clinical limit for exposure to static magnetic fields as set by the Food and Drug Administration?**
  - a. Less than 1.0 T
  - b. Less than 2.0 T
  - c. Less than 4.0 T
  - d. Less than 7.0 G
7. **What are the significant bioeffects of exposure to static magnetic fields below 2.0 T?**
  - a. Hearing loss
  - b. Tinnitus, dizziness, flashes of light
  - c. Hypertension, sleeplessness
  - d. No significant bio-effects
8. **The magnetohydrodynamic effect can be seen as a (an)**
  - a. flash of light.
  - b. peripheral muscle contraction.
  - c. elevation in the S-T segment of the patient's electrocardiogram.
  - d. blurry line in the images.
9. **The liquid forms of gasses are called**
  - a. cryogens.
  - b. liquidics.
  - c. condensation.
  - d. by the same name followed by an (L), that is, helium (L).
10. **What is rapid and uncontrolled boil-off of cryogens called?**
  - a. Venting crisis
  - b. Quench
  - c. Cryogenic evacuation
  - d. Meltdown
11. **The function of the gradient magnetic field(s) is to control**
  - a. selective excitation of protons.
  - b. excitation and relaxation.
  - c. alignment of protons.
  - d. signal generated by the protons.
12. **What is the unit of measure of strength for gradient magnetic fields?**
  - a. C/kg
  - b. G/cm
  - c. T/sec
  - d. W/kg
13. **Flashes of light believed to be caused by direct stimulation of the retina and/or optic nerve are called**
  - a. magnetophosphenes.
  - b. floaters.
  - c. starry eyes.
  - d. retinitis cometosis.
14. **What is the Food and Drug Administration limit on the exposure to gradient magnetic fields?**
  - a. Below 93 decibels
  - b. Below the level required for peripheral nerve stimulation
  - c. 0.4 W/kg
  - d. Less than 2 T/sec
15. **What two areas of the body are unable to efficiently dissipate heat?**
  - a. Nasal sinuses and liver
  - b. Testicles and ovaries
  - c. Testicles and eyes
  - d. Kidneys and gallbladder
16. **What criterion must be met before an MRI can be performed on a pregnant women?**
  1. The obstetrician agrees that the examination is necessary.
  2. The patient specifically requests the test.
  3. The patient has had an MRI in the past without incident.
  4. The diagnostic benefits outweigh the potential risks.
    - a. 1 and 2
    - b. 2 and 3
    - c. 1 and 4
    - d. 1, 2, 3, and 4
17. **The acoustic noise in MRI is caused by the**
  - a. rapid cycling of power to the gradient coils.
  - b. rapid cycling of power to the Rf coil.
  - c. radio waves moving at the speed of sound.
  - d. momentary expansion of the coil windings due to heat.

**18. What element do ferromagnetic materials contain?**

- a. Tin
- b. Niobium
- c. Iron
- d. Gadolinium

**19. The attractive force experienced by a ferromagnetic object is**

- a. inversely proportional to the square of the object's distance from the isocenter.
- b. proportional to the distance of the object from the isocenter.
- c. relatively weak and will not dislodge even small objects.
- d. dependent on the speed of the gradient coils.

**20. What items should be tested before they are allowed into the MRI suite?**

- a. Items believed to contain metal
- b. Items not specifically designed for MRI
- c. Items manufactured before 1995
- d. All items to be used in the MRI suite



Enterprises for Continuing Education, Inc.  
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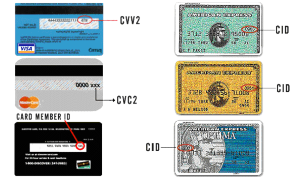
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Article Title: **Basic Principles of MRI Safety**

Office Use: MR59

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2. a b c d	7. a b c d	12. a b c d	17. a b c d
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